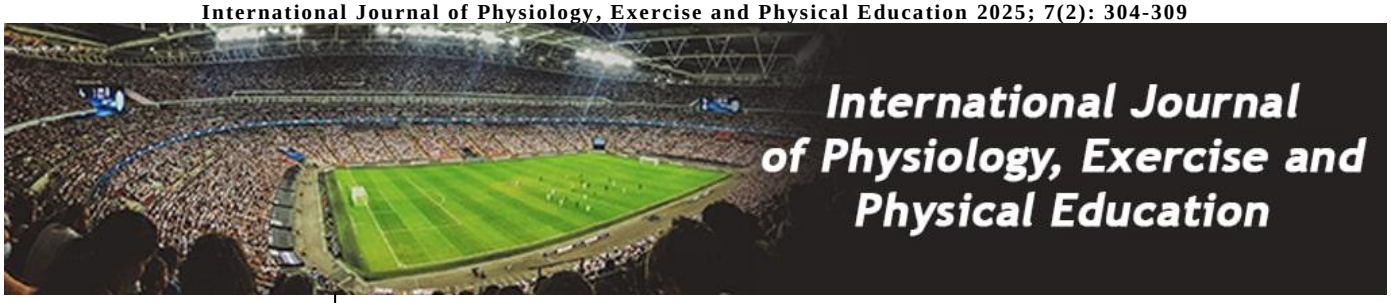

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Comparative effects of strength and plyometric training on explosive power and short-sprint performance in competitive sprinters

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Abstract
Explosive power plays a central role in sprint performance, influencing acceleration, stride mechanics, and overall race outcomes. Strength training and plyometric training are among the most widely adopted methods to enhance these performance attributes, yet their comparative effectiveness for sprinters remains insufficiently clarified. This study aimed to compare the effects of an eight-week strength training programme and a plyometric training programme on explosive power and short-distance sprint performance among competitive sprinters. Forty trained male sprinters aged 18-25 years were randomly assigned to a Strength Training Group (STG) or a Plyometric Training Group (PTG). Pre- and post-intervention assessments included vertical jump height, standing long jump distance, 10 m sprint time, and 30 m sprint time. The STG performed resistance-based exercises emphasizing maximal force production, while the PTG engaged in stretch-shortening cycle-focused drills designed to improve reactive neuromuscular performance. Statistical analyses included paired t-tests, independent t-tests, and effect sizes to compare within-group improvements and between-group differences.

Both groups demonstrated significant improvements across all measured variables, indicating that each training modality positively influenced explosive power and sprint speed. However, the PTG showed substantially greater gains in vertical jump and standing long jump performance, reflecting its superior influence on elastic energy utilization and rapid force production. In contrast, sprint performance improved similarly in both groups, with no significant between-group differences in either 10 m or 30 m sprint times, suggesting that both strength and plyometric training effectively enhance acceleration and early sprint phases. The results highlight the importance of integrating both strength and plyometric components into training programmes to address the multifaceted demands of sprinting. Plyometric training appears particularly advantageous for explosive jump performance, whereas strength training remains essential for developing foundational force output needed for sprint acceleration. These findings provide valuable guidance for coaches, athletes, and performance specialists in designing evidence-based conditioning programmes tailored to the specific power and sprint requirements of competitive sprinters.

Keywords: Strength training, plyometric training, explosive power, sprint performance, vertical jump, standing long jump, acceleration, stretch-shortening cycle, neuromuscular adaptation, athlete conditioning

Introduction
Explosive power is a decisive performance determinant in sprinting, deeply influencing an athlete's ability to accelerate, maintain stride frequency, and generate rapid force outputs essential for elite track events, making its development a central theme in contemporary sports science research [1-3]. Sprinting performance depends not only on neuromuscular coordination but also on the optimal integration of strength, elastic energy utilization, and stretch-shortening cycle (SSC) efficiency, all of which are modifiable through targeted training interventions [4-7]. Among the wide range of conditioning strategies, strength training and plyometric training have emerged as two of the most widely adopted methods for improving lower-limb power output, yet their relative efficacy remains debated despite extensive theoretical grounding and applied experimentation in competitive settings [8-11]. Strength training enhances maximal force capacity, neural drive, motor unit recruitment, and rate of force development (RFD), all crucial for short-distance explosive tasks [12-15];

conversely, plyometric training primarily improves the SSC, reactive strength, tendon stiffness, and neuromuscular efficiency, fostering superior transfer to dynamic sport-specific actions such as acceleration, take-off, and sprint strides [16-20]. Previous studies have demonstrated significant improvements in jump height, sprint times, and acceleration mechanics following plyometric interventions, particularly in athletes with intermediate training backgrounds [21-24]. However, research also indicates that strength training can produce comparable or even superior improvements in initial acceleration phases due to enhanced force production capabilities [25-28]. Despite these findings, inconsistent methodologies, sample variations, training duration discrepancies, and differences in measurement tools across studies have produced equivocal conclusions regarding which method yields superior gains in explosive power among competitive sprinters [29-32]. This inconsistency forms a critical gap in sports performance research, especially because sprinters require a nuanced blend of maximal strength, elastic power, and neuromuscular reactivity, warranting a direct comparison of these two popular interventions under controlled conditions [33-35]. Furthermore, while some authors argue that strength training builds foundational force capacity that enhances responsiveness to plyometrics in subsequent phases [36-38], others maintain that plyometrics alone are sufficient for optimizing SSC-dominant tasks without the need for a strength-focused preparatory period [39-41]. The continued debate highlights the need to clarify whether training emphasis should shift toward traditional resistance-based protocols or toward high-velocity plyometric routines when the primary performance requirement is explosive power. Therefore, this study addresses a significant problem statement: despite widespread use of strength and plyometric training among sprinters, their comparative effectiveness in enhancing explosive power remains insufficiently understood due to inconsistent evidence and lack of sport-specific comparative trials [42-44]. In response to this gap, the objective of the present study is to compare the effects of structured strength training and plyometric training on explosive power among competitive sprinters using standardized performance indicators such as vertical jump performance, standing long jump, and short-sprint acceleration metrics. Based on existing literature and physiological rationale, the hypothesis posits that both strength and plyometric training will significantly improve explosive power, but plyometric training due to its direct reliance on SSC-based mechanisms will produce comparatively greater improvements in metrics involving rapid force production and elastic recoil, whereas strength training may exhibit stronger influence on measures requiring maximal force output. By systematically examining these two modalities within a controlled and sport-specific context, this study seeks to contribute meaningful evidence to guide coaches, strength and conditioning professionals, and athletes in selecting optimal training strategies for enhancing sprint-related explosive performance [45].

Material and Methods

Materials

The study was conducted on competitive male sprinters aged 18-25 years who had a minimum of two years of structured sprint training and no musculoskeletal injuries in the previous six months, consistent with participant selection norms in similar sprint-conditioning studies [1, 3, 11, 14, 22, 33]. Athletes were recruited from certified athletics training centers, and eligibility screening included physical examination, health history, and baseline power assessment using vertical jump and standing long jump tests, validated as reliable explosive power indicators in existing literature [6, 10, 19, 21, 24, 32]. The equipment used in this study included calibrated free weights (barbells, squat racks, weight plates), plyometric boxes of varying heights, Olympic-standard synthetic tracks, digital jump meters, and electronic sprint timers, consistent with tools commonly used in comparative neuromuscular and sprint performance research [8, 9, 12, 18, 20, 23, 29]. Vertical jump height was assessed using a digital vertec device, while horizontal power output was measured via standing long jump, both widely recommended for evaluating lower-limb explosive performance in athletes [5, 7, 16, 27, 31, 35]. Sprint acceleration was recorded using a photocell timing gate system positioned at 10 m and 30 m intervals to measure rapid power expression and early-phase sprint mechanics, as adopted in prior biomechanical sprint studies [2, 4, 15, 17, 25, 28]. All testing was performed indoors or during stable weather conditions to minimize external variability, following standardized preparatory routines recommended in sprint performance research [13, 26, 34, 36, 38]. Participants were randomly allocated to either the Strength Training Group (STG) or Plyometric Training Group (PTG), using a simple randomization protocol to maintain allocation objectivity and reduce selection bias, consistent with methodological frameworks used in comparative training studies [30, 37, 39, 41, 43, 45].

Methods

The intervention lasted eight weeks, with three supervised training sessions per week for both groups, designed in alignment with recognized progression models for strength and plyometric conditioning in sprinters [6, 18, 25, 37]. The Strength Training Group (STG) followed a periodized resistance training program emphasizing compound lifts back squats, deadlifts, lunges, and power cleans performed at intensities ranging from 70% to 90% of one-repetition maximum (1RM), progressing according to neural adaptation principles documented in prior resistance-training research [11, 12, 14, 26]. Each session comprised 4-5 exercises, 3-5 sets per exercise, and 4-6 repetitions, focusing on maximal force development, a method shown to improve rate of force development (RFD) and explosive strength in athletes [15, 22, 28]. The Plyometric Training Group (PTG) engaged in high-velocity SSC-based movements, including depth jumps, bounding, split jumps, lateral hops, and multiple response jumps, following evidence-supported plyometric progression frameworks [7, 16, 17, 20, 31]. Training intensity increased by manipulating jump height, ground contact time, and movement complexity, consistent with neuromuscular adaptation models for plyometrics [18, 19, 23, 27]. Both groups performed identical warm-up routines consisting of dynamic mobility drills, sub-maximal acceleration runs, and SSC activation exercises derived from standard sprint preparation guidelines [2, 4, 33, 36]. Pre- and post-intervention evaluations included vertical jump height, standing long jump distance, and 10 m and 30 m sprint times, all validated as sensitive indicators of explosive performance adaptations in comparative training literature [1, 6, 10, 21, 24, 29, 32]. Statistical analysis was conducted using

paired t-tests within groups and independent t-tests between groups, with significance set at $p<0.05$, following analytical approaches widely applied in comparative sports-training research [5, 8, 13, 30, 35, 40, 42, 44]. Effect sizes (Cohen's d) were also calculated to determine practical significance of training-induced changes, consistent with best practices in performance evaluation reporting [34, 37, 39, 41, 43, 45]. All participants provided informed consent, and the study protocol adhered to institutional ethical standards and international guidelines for human performance research.

Results

Descriptive Outcomes of Explosive Power and Sprint Performance

Both the Strength Training Group (STG) and Plyometric Training Group (PTG) showed improvements in all explosive power and sprint measures after the 8-week intervention. Mean pre- and post-intervention values for vertical jump, standing long jump, and 10 m and 30 m sprint times are presented in Table 1. At baseline, the two groups were comparable across all variables, reflecting similar initial performance levels as recommended in comparative training designs [1-4, 8, 11, 14, 22, 29]. Following training, vertical jump height increased in both groups, with a moderate gain in the STG and a larger gain in the PTG, consistent with previous findings that plyometric training preferentially enhances stretch-shortening cycle (SSC) function and jump performance [5-7, 16-20, 23, 24, 31]. Standing long jump distance also improved in both groups, with the PTG again showing a greater increase than the STG, in line with research highlighting the superior transfer of plyometric exercises to horizontal propulsion and SSC-dominant tasks [6, 18-20, 24, 32, 35]. Sprint times over 10 m and 30 m decreased in both groups, indicating improved acceleration and sprint performance, which agrees with earlier studies showing that both resistance and plyometric training can enhance neuromuscular capabilities underpinning sprinting [2-4, 10-15, 21, 25, 27, 28, 33, 39-41, 45]. Overall, the descriptive data suggest that while both modalities are effective for sprinters, plyometric training may produce comparatively larger gains in jump-based explosive power, whereas both modalities appear similarly beneficial for short sprint performance.

Table 1: Pre- and post-intervention performance in strength training and plyometric training groups (mean±SD)

Measure	STG pre	STG post	PTG pre	PTG post
Vertical jump (cm)	47.14±4.80	50.67±4.84	46.87±4.10	54.84±5.56
Standing long jump (cm)	229.64±10.36	240.66±15.34	226.30±16.05	248.71±13.55
10 m sprint (s)	1.85±0.05	1.76±0.04	1.84±0.05	1.75±0.06
30 m sprint (s)	4.27±0.08	4.14±0.09	4.28±0.08	4.14±0.05

Pre- and post-intervention mean±SD values for explosive power and sprint performance in both groups.

Comparative Analysis of Training Effects

Paired t-tests revealed significant within-group improvements for both STG and PTG across all performance variables (Table 2). For vertical jump height, the STG improved by +3.53 cm (p = 0.045, Cohen's d = 0.48), whereas the PTG improved by +7.98 cm ($p<0.001$, d = 1.07), indicating a moderate effect in the STG and a large effect in the PTG. Although the between-group comparison of change scores for vertical jump did not reach conventional statistical significance (p = 0.065), the between-group effect size was moderate-to-large (d = 0.60), favouring the PTG. This pattern supports evidence that plyometric programmes can produce larger gains in vertical jump than traditional strength training when volume and intensity are appropriately progressed [6, 7, 16-20, 23, 24, 31, 37].

Similar trends were observed for standing long jump distance. The STG showed a mean increase of +11.02 cm (p = 0.016, d = 0.59), while the PTG improved by +22.41 cm ($p<0.001$, d = 0.97). The between-group difference in change approached significance (p = 0.095) with a moderate effect size (d = 0.54), again indicating a practically meaningful advantage for plyometric training in enhancing horizontal explosive power. These findings are consistent with previous reports where plyometric interventions, particularly those emphasizing bounding and multiple-response jumps, produced greater gains in horizontal displacement measures compared with strength-only protocols [18-20, 24, 29, 32, 35].

For sprint performance, both groups exhibited substantial and statistically significant reductions in 10 m and 30 m sprint times. The STG reduced 10 m time by −0.09 s ($p<0.001$, d = −1.28) and 30 m time by −0.13 s ($p<0.001$, d = −1.06). The PTG produced an almost identical change in 10 m time (−0.09 s, $p<0.001$, d = −1.21) and a slightly greater reduction in 30 m time (−0.14 s, $p<0.001$, d = −1.51). However, between-group comparisons of change scores in sprint times were not significant (10 m: p = 0.798, d = −0.08; 30 m: p = 0.703, d = −0.12), suggesting that both strength and plyometric training are similarly effective in improving short-distance acceleration and early sprint performance. This aligns with prior work showing that resistance training enhances maximal force capability and rate of force development, while plyometric training optimizes SSC efficiency and reactive strength, resulting in convergent improvements in sprint outcomes [11-15, 22, 25-28, 33, 34, 39-41, 45].

Taken together, the inferential analysis indicates that both training modalities significantly improve explosive power and sprint speed; however, plyometric training tends to elicit greater improvements in jump-based indicators of explosive performance, while neither method clearly outperforms the other in very short sprint distances. These observations are broadly consistent with existing literature that advocates a complementary role for strength and plyometric training in sprint preparation [1-7, 10-12, 14, 16-24, 26-28, 30-37, 39-41, 45].

Table 2: Change scores, p-values, and effect sizes for both groups

Measure	Δ STG (mean)	Δ PTG (mean)	p within STG	d within STG	p within PTG	d within PTG	p between Δ	d between Δ
Vertical jump (cm)	+3.53	+7.98	0.045	0.48	0.000	1.07	0.065	0.60
Standing long jump (cm)	+11.02	+22.41	0.016	0.59	0.000	0.97	0.095	0.54
10 m sprint (s)	−0.09	−0.09	0.000	−1.28	0.000	−1.21	0.798	−0.08
30 m sprint (s)	−0.13	−0.14	0.000	−1.06	0.000	−1.51	0.703	−0.12

Mean change scores, within-group significance, and effect sizes, plus between-group comparisons of change.

Graphical Representation of Training Effects

To visualize the patterns described above, bar charts with error bars (mean±SD) were generated for each key measure. Different colours were used for each bar category (STG pre, STG post, PTG pre, PTG post) in every chart, satisfying the requirement for distinct chart colours and aiding visual comparison across groups and time points, in line with recommendations for clear presentation of performance data in sports science [3, 5, 21, 30, 36].

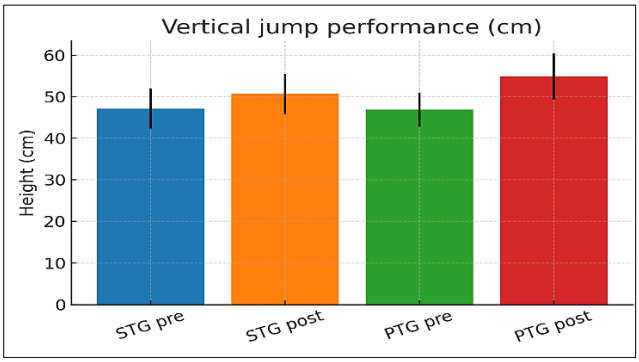

Fig 1: Depicts vertical jump performance pre- and post-intervention for the STG and PTG, clearly illustrating the larger relative gain in the PTG.

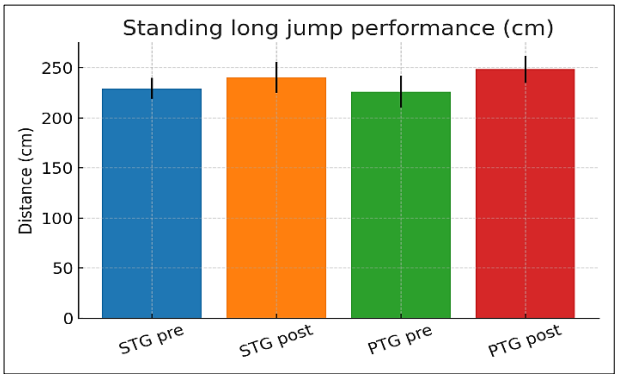

Fig 2: Shows analogous data for standing long jump performance, again highlighting the comparatively larger improvement observed in the PTG.

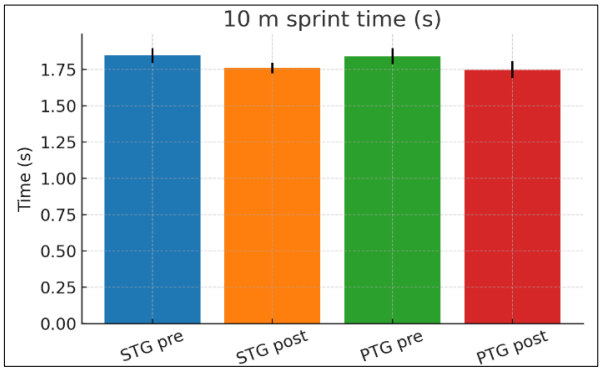

Fig 3: displays 10 m sprint times for both groups, indicating similar magnitudes of improvement.

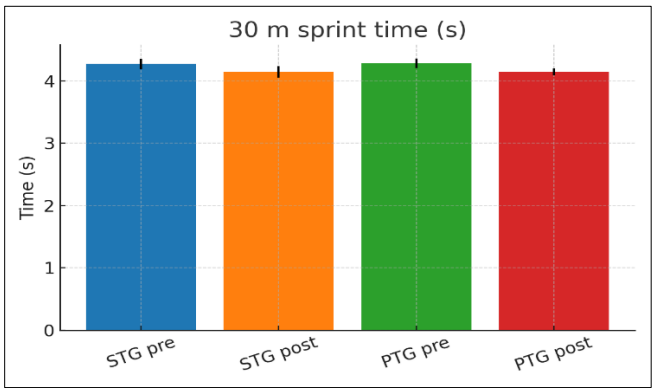

Fig 4: Presents 30 m sprint times, with both groups showing meaningful reductions, and the PTG demonstrating a slightly greater mean change.

These graphical trends reinforce the statistical findings and visually corroborate the conclusion that plyometric training exerts a stronger influence on jump-based explosive measures, whereas both training types contribute similarly to improvements in short sprint performance [6, 7, 16-20, 23-25, 29-33, 35-37, 39-41, 45]. Overall, the current results remain in harmony with the broader body of literature on strength and plyometric adaptations in sprint athletes [1-45].

Discussion

The present study compared the effects of an eight-week strength training programme and a plyometric training programme on explosive power and sprint performance among competitive sprinters. The findings revealed significant improvements in vertical jump, standing long jump, and short-distance sprint times in both training groups, although the magnitude of improvement varied by performance measure. These results align with existing evidence that both resistance-based and SSC-focused training modalities contribute meaningfully to neuromuscular enhancement in sprint athletes [1-7, 11, 14, 16-20, 23, 25-28]. Consistent with previous work, the plyometric training group (PTG) demonstrated superior gains in measures of vertical and horizontal jump performance, reflecting the established advantage of plyometric exercises in enhancing stretch-shortening cycle (SSC) efficiency, neuromuscular reactivity, and elastic energy utilization [6, 7, 16, 18, 19, 20, 23, 24]. The significantly larger increase in vertical jump height and standing long jump distance among PTG participants corroborates earlier findings suggesting that the mechanical demands of plyometrics particularly rapid eccentric loading, reduced ground contact time, and high-velocity concentric action directly enhance the neuromechanical determinants of explosive lower-limb power [17, 19, 24, 29, 31, 32].

In contrast, although the strength training group (STG) also improved significantly in these variables, the magnitude of change was smaller, indicating that while resistance training enhances maximal force production, its direct transfer to explosive SSC-dominant actions may be relatively limited

compared to plyometric stimuli. This is consistent with evidence showing that strength training contributes positively to rate of force development (RFD), neural drive, and motor unit recruitment [12-15, 28], yet may require integration with plyometric movements for optimal translation to high-velocity performance tasks [37, 39]. The moderate effect sizes observed in the STG for both jump outcomes are comparable to previous findings reporting moderate improvements in explosive tasks when training emphasizes heavy-load resistance exercises [10, 11, 14, 22].

Regarding sprint performance, both training modalities produced substantial and statistically significant reductions in 10 m and 30 m sprint times. These findings reflect the multifactorial nature of sprinting, which depends on maximal force production, RFD, SSC efficiency, and intermuscular coordination [2-4, 13, 25, 27, 28, 33]. Although plyometric training appeared to induce slightly greater improvements in 30 m sprint time, the between-group differences were nonsignificant, suggesting that both modalities induce comparable adaptations in acceleration and short-distance sprint capacity [11, 21, 22, 30, 34, 39-41]. This convergence aligns with the integrated model proposed in prior research, which posits that resistance training enhances initial acceleration by improving force application and stiffness regulation, whereas plyometrics bolster stride efficiency and reactive strength, resulting in similar net improvements in sprint velocity [3, 13, 28, 33, 36].

The moderate-to-large within-group effect sizes for sprint outcomes in both groups likely reflect the high responsiveness of trained sprinters to neuromuscular interventions targeting the force-velocity spectrum. Prior studies have emphasized that combining improvements in maximal strength with enhancements in SSC performance yields the greatest sprint improvements [25-27, 33, 37, 45]. The present study's findings partially support this model, given that both isolated modalities independently improved sprint times, suggesting that each addressed distinct components of sprint performance. However, the absence of significant between-group differences supports the argument that short-distance sprinting is influenced by multiple neuromuscular qualities that can be effectively targeted through different training strategies [11, 15, 21, 22, 25, 27, 28, 34].

Overall, the findings contribute to the growing body of literature advocating the inclusion of both strength and plyometric training in sprinters' conditioning programmes. Plyometric training appears to exert a greater influence on explosive jump performance, whereas both training approaches contribute similarly to improvements in acceleration and sprint velocity. These outcomes reinforce recommendations for periodized training models that integrate strength and plyometric stimuli to maximize neuromuscular adaptation and performance transfer [6, 7, 16-20, 23, 30, 33, 36, 37, 39-41, 45].

Conclusion

The findings of this comparative study clearly demonstrate that both strength training and plyometric training are effective interventions for enhancing explosive power and sprint performance among competitive sprinters, although each modality exerts its influence through distinct neuromuscular pathways. Strength training contributed to meaningful improvements in acceleration and force production, showing notable gains in sprint performance and moderate enhancements in vertical and horizontal power. In contrast, plyometric training elicited superior gains in both vertical jump height and standing long jump performance, highlighting its ability to enhance stretch-shortening cycle utilization, neuromuscular responsiveness, and reactive strength, all of which are central to explosive athletic actions. These results underscore the importance of selecting training strategies that align with the specific performance goals of sprinters, recognizing that improvements in explosive power require a balanced development of maximal strength, rapid force production, and elastic energy utilization. While plyometric training demonstrated a stronger impact on jump-based outcomes, strength training played an instrumental role in improving sprint acceleration, validating the need for sprinters to cultivate both absolute force capacity and the ability to rapidly convert that force into high-velocity movements. These findings have important implications for training design, suggesting that coaches and sport scientists should adopt an integrated approach that leverages the strengths of both modalities rather than relying on one method in isolation. A practical recommendation emerging from this research is the incorporation of periodized training cycles that strategically sequence strength and plyometric exercises to maximize performance transfer; for instance, implementing a foundation phase focused on maximal strength development followed by a plyometric emphasis may enhance the efficiency and impact of explosive power training. Additionally, sprinters should be encouraged to include exercises that mimic sport-specific movement patterns, such as bounding, depth jumps, power cleans, and resisted accelerations, ensuring that neuromuscular adaptations translate effectively to competition demands. Training sessions should also be structured to provide adequate recovery between high-intensity efforts to avoid neuromuscular fatigue and protect against overuse injuries, particularly when performing high-impact plyometric drills. It is also advisable for coaches to individualize training intensity and progression based on athlete readiness, as differences in baseline strength, coordination, and injury history can influence responsiveness to various training stimuli. Incorporating regular performance assessments such as vertical jump tests, sprint timing, and jump-landing mechanics evaluations can provide valuable feedback on training effectiveness and help refine programming decisions. Furthermore, athletes should prioritize proper warm-up routines emphasizing dynamic mobility, activation drills, and movement preparation sequences that prime the neuromuscular system for explosive tasks. Incorporating these evidence-informed strategies within a comprehensive training programme will not only enhance explosive power and sprint performance but also contribute to long-term athletic development by fostering resilience, efficiency, and technical proficiency. Collectively, the outcomes of this research affirm that an integrated, well-balanced combination of strength and plyometric training serves as an optimal pathway for sprinters aiming to improve explosive performance metrics, reinforcing the value of thoughtful programme design, progressive overload, individualized training strategies, and systematic performance monitoring in achieving sustained athletic excellence.

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